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SOME APPLICATIONS OF THE VARIATION OF HYDROGEN OVERVOLTAGE WITH THE PRESSURE

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In a previous communication[1] it was shown that the hydrogen overvoltage at a given electrode can be expressed, at low current densities, with a considerable degree of approximation, by the equation:

$$2FE = \frac{3RT}{pr}\gamma$$

in which E, r, p, and γ are, respectively, the overvoltage, the radius of the hydrogen bubbles, the pressure, and the surface tension. The value of r was found experimentally to be independent of the pressure, and a plot of the variation of the overvoltage with the pressure was found to follow, very nearly at least, the hyperbola required by the above expression.

It next became interesting to investigate some chemical processes in which hydrogen overvoltage is intimately involved in order to see whether changes in these processes, produced by variations in the external pressure, are also in the direction predicted by the theory. Three such processes are: (1) the corrosion of metals in acid solutions, (2) reduction in acid solutions by metals, and (3) the electrodeposition of metals.

1. Metal Corrosion.—When a metal above hydrogen in the electromotive series is placed in a solution of an electrolyte there is a tendency for the metal to ionize; i.e., to split into ions and electrons; for instance, with iron, the following reaction tends to take place

$$Fe = Fe^{++} + 2e, \qquad (1)$$

(e = electron). However, no chemical action will ensue unless another reaction, involving the absorption of the electrons liberated in Reaction 1, can also occur. In the absence of oxidizing agents the only possible reaction is

$$2H^+ + 2e = H_2 \qquad (2)$$

Any factor which tends to decrease the velocity of Reaction 2, i.e., which increases the overvoltage, will decrease the corrosion represented by Reaction 1. Watts and Whipple[2] have found that, contrary to statements in the chemical literature, a decrease of the external pressure will produce a decrease of corrosion of metals in acids. These workers, however, attribute the decreased corrosion to the absence of air in the solutions which were under reduced pressure. As it seemed probable to us that the effect is, largely at least, due to an increase in the overvoltage with decreased pressure, we repeated their experiments, taking care to exclude oxygen from the acid. Table 1, which contains

TABLE 1

METAL	LOSS IN WEIGHT	
	At 1 atmospheric pressure	At $\frac{1}{10}$ atmospheric pressure
	gram	*gram*
Zn	0.0927	0.0594
Fe	0.0797	0.0469
Cd	0.0018	0.0018

typical results for Zn, Fe, and Cd, shows that the effect of decreased pressure on the corrosion of the first two of these metals is in the direction predicted. No bubbles of hydrogen were observed to leave the surface of the cadmium, so no change of overvoltage, and therefore no change of the corrosion, with the pressure is to be expected.

2. Reduction, in Acid Solutions, by Metals.—On placing a strip of iron into a slightly acidified solution of $FeCl_3$ the metal enters solution according to Reaction 1. The two ionic reactions that compete, so to speak, for the liberated electrons are

$$Fe^{+++} + e = Fe^{+++} \qquad (3)$$

and Reaction 2. Here we can predict that a decrease of pressure will, by increasing the overvoltage, reduce the velocity of Reaction 2, with the result that Reaction 3 will be favored. The experimental results of a series of measurements are plotted in figure 1, in which abscissas represent pressures and ordinates reduction in a given time. Due to

irregularities in the surface of the iron the points are scattered, but the trend is clearly the same as that of the overvoltage-pressure curves given in the previous paper. This appears to be a promising method of increasing the speed and efficiency of a large class of reductions.

3. The Electrodeposition of Metals.—If hydrogen were evolved at a cathode at its reversible potential under all conditions no metal higher in the electromotive series than hydrogen could be deposited electrolytically from an aqueous solution. Due to hydrogen overvoltage, however, it is possible to obtain deposits of these metals as high in the

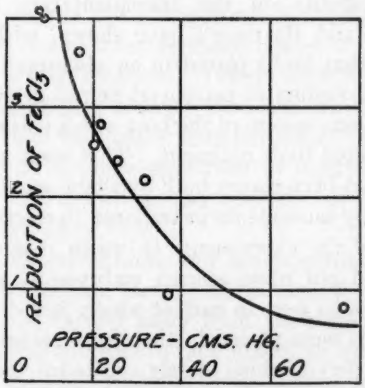

FIG. 1

series as zinc. The current efficiency of such a deposition depends, mainly, upon the relative magnitudes of the potential between the solution and the metal, and the hydrogen overvoltage of the metal; the efficiency increasing, of course, with an increase of the overvoltage. The figures in table 2 indicate that the increase of hydrogen overvoltage produced by a decrease of pressure is accompanied, in the case of the deposition of zinc, by an increase in the efficiency of the deposition. These depositions were all made from the same solution, and at the same current density and temperature.

TABLE 2

Pressure, *cms. Hg*	76	13	12	6
Efficiency, *per cent*	75	81	92	97.5

[1] These Proceedings, May, 1919, also *J. Amer. Chem. Soc.*, 41, 1919, (194).

[2] *Trans. Amer. Electrochem. Soc.*, 32, 1917, (257).

THE EFFECTS OF TRANSPLANTING LIMBS UPON THE FORMATION OF NERVE PLEXUSES AND THE DEVELOPMENT OF PERIPHERAL NEURONES

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Communicated by R. G. Harrison, June 6, 1919

Previous experiments on the transplantation of limbs (Braus,[1] Banchi,[2] Gemelli[3] and Harrison[4]) have shown, with the exception of those of Banchi, that limbs placed in an abnormal (heterotopic) position will acquire a system of peripheral nerves derived from that part of the central nervous system of the host which corresponds to the position of the implanted limb rudiment. That such nerves may be partially functional has been shown both by slight spontaneous movements of the limbs and by movements in response to electrical stimulation.

The majority of the experiments to which reference has just been made were carried out upon anuran embryos at a period when the peripheral nerve paths were in part or wholly laid down. Accordingly, the limb rudiments were placed in the direct pathway of one or more developing spinal nerves which merely continued their growth into the rudiment so placed. In all of these experiments the transplanted limb was developed from an additional rudiment, taken from another embryo, the normal limb rudiments of the host being left intact.

Experiments carried out by the author upon the urodele, Amblystoma punctatum, in which the anterior limb rudiment was transplanted to an abnormal position at a period prior to initial outgrowth of the spinal nerves, strongly suggest that the limb exerts a guiding influence upon the segmental nerve supply and determines the path taken by the spinal nerves effecting its innervation. The positive reaction towards this influence appears to be greater in the nerves developing from the normal limb level of the cord than in those developing from more posterior segments of the cord.

Positive evidence has also been found to show that the functional activity of the transplanted limb has initiated a hyperplasia of the peripheral afferent neurones, the spinal ganglia connected with the heterotopic limb being considerably larger than their counterparts which do not supply an homologous organ. Evidence that the ganglionic hypertrophy has been brought about by an actual hyperplasia

of the elements has been obtained by making a count of the ganglion cells.

Although diligent search has been made, no evidence has as yet been obtained to show that the functional activity of the transplanted limb has effected a hyperplasia of the peripheral somatic motor neurones, there being no constant differences in size between the motor horn areas supplying the heterotopic limb and the opposite side where the limb is not present.

The experiments were carried out upon embryos in the so-called tail bud stage (stage 29). In the majority of the experiments the anterior limb rudiment was excised and re-implanted in the same embryo at distances ranging from one to seven segments posterior to the normal position (autoplastic transplantation). Other experiments consisted of transplanting an additional anterior limb rudiment to an embryo in which the normal limb rudiments were left intact (homoplastic transplantations). The larvae were preserved at intervals from thirty to eighty days after the operation, the majority of cases being under observation for about sixty days.

The results of the transplantations are presented in table 1. The figures in table 1 A illustrate the significant fact, that, as the limbs are implanted farther and farther away from the normal situation, there occurs a corresponding decrease in their ability to function until a position is reached (six segments posterior to the normal, series AS6) in which all exhibit very imperfect movements, there being no cases with perfect adaptive function.

Additional anterior limbs transplanted successively three, four and five segments posterior to the normal intact limb of the host (table 1 B), while exhibiting slight twitching movements in cases, never attain the completeness of function reached by autoplastic limbs implanted in the same relative position.

The gradual decrease in the function of the autoplastic limbs as they are implanted more and more remote from the normal limb region seems to be directly correlated with the segmental nerve contribution (table 2).

The normal anterior limb is supplied by a plexus composed of the third, fourth and fifth spinal nerves (fig. 1). In the tail bud stage of embryonic development the anterior limb rudiment constitutes a slightly thickened region of somatopleural mesoderm lying just ventral to the pronephros and extending from the anterior border of the third somite to the posterior border of the fifth.

TABLE 1

A. Showing the results of transplanting the right anterior limb rudiment a number of segments (AS1, AS2, AS3, etc.) posterior to its normal position.

B. Showing the results of transplanting an additional anterior limb rudiment to an embryo in which the normal limb rudiments have been left intact. HS3, HS4 and HS5 indicate the successive number of segments the additional limb rudiment was implanted posterior to the normal right anterior limb of the host.

	SERIES	OPERATIONS	EXPERIMENTS POSITIVE	NORMAL LIMBS		REDUPLICATIONS		FUNCTIONAL LIMBS		NO FUNCTION		FUNCTION IMPAIRED		FUNCTION PERFECT	
				Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
A	AS1	25	20	19	95	1	5	20	100	0	0	1	5	19	95
	AS2	21	18	17	94.5	1	5.5	17	100	0	0	3	16.7	15	83.3
	AS3	24	17	13	76.5	4	23.5	15	88.2	2	11.8	4	23.5	11	64.7
	AS4	34	29	18	67.0	11	33	23	79.3	6	20.7	11	37.9	12	41.4
	AS5	35	30	11	36.7	19	63.3	20	66.7	10	33.3	16	53.3	4	13.4
	AS6	35	29	22	75.9	7	24.1	15	51.7	14	48.3	15	51.7	0	0
B	HS3	10	9	2	22.2	7	77.8	9	100	0	0	6	66.7	3	33.3
	HS4	30	21	8	38.1	13	61.9	11	52.4	10	47.6	11	52.4	0	0
	HS5	30	25	11	44.0	14	56.0	13	52.0	12	48.0	13	52.0	0	0

TABLE 2

Showing the segmental nerve contribution to the anterior limb when implanted successively a number of segments (1 to 7) posterior to its normal position.

SERIES	CASE	POSITION OF LIMB NUMBER OF SEGMENTS POSTERIOR TO NORMAL	SEGMENTAL NERVE CONTRIBUTION								
			3	4	5	6	7	8	9	10	11
Normal	1	0	3	4	5						
AS1	12	1	3	4	5						
AS2	5	2	3	4	5						
AS2	12	2	3	4	5						
AS3	9	3		4	5	6					
AS3	18	3		4	5	6					
AS4	12	4		4	5	6	7				
AS4	27	4				6	7	8			
AS4	26	4			5	6	7				
AS4	30	4			5	6	7				
AS5	25	5			5	6	7	8	9		
AS5	27	5				6	7	8	9		
AS5	23	5					7	8	9		
AS5	30	5				6	7	8	9		
AS5	26	5					7	8	9		
AS6	29	6						9	9	10	
AS6	5	6							9	10	
AS7	5	7								10	11

The outgrowing third, fourth and fifth spinal nerves in Amblystoma, effecting connection with the limb rudiment at a period when it occupies its maximum extent (anterior border of the third somite to the posterior border of the fifth), become converged into a plexus as a result of concentration of the rudiment into the definitive limb bud which centers under the fourth myotome. Such convergence having taken place, a typical normal plexus as illustrated in figure 1 is produced.

However, in the examination of the segmental nerve supply to the anterior limb when transplanted posteriorly through distances ranging from one to seven segments, it is found that limbs so placed receive the

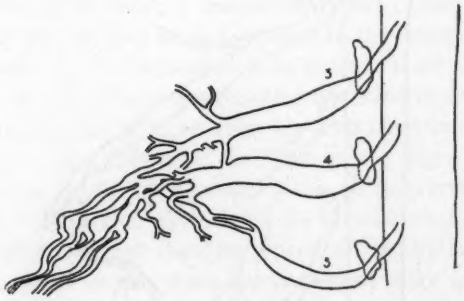

FIG. 1. GRAPHIC RECONSTRUCTION OF THE NORMAL LEFT BRACHIAL PLEXUS OF CASE AS4[26], PRESERVED SIXTY-EIGHT DAYS AFTER THE OPERATION. × 20

bulk of their nerve components from spinal segments situated anterior to the implanted limb rudiment rather than from segments corresponding to the new position of the limb (table 2 and fig. 2).

As has been observed previously, a very significant feature of table 2 illustrates the tendency of the transplanted limbs to be innervated by the nerves developing from the normal limb level of the cord, this tendency being most marked in the fourth and fifth nerves both of which, in the cases studied, were found to elongate in a postero-lateral direction a greater distance to effect innervation than did the third nerve or those developing from segments of the cord posterior to the normal limb level.

Anterior limbs when implanted the distance of one or two segments posterior to the normal position receive the normal segmental nerve contribution (table 2, series AS1 and AS2). The function of such

limbs is practically as complete as that of the limbs in their normal position. When transplanted posteriorly the distance of three segments, the third spinal nerve no longer contributes to the innervation of the limb and the function of limbs in this position is less complete (table 2, series AS3).

When transplanted posteriorly the distance of four segments, all cases studied, with one exception, show that the fourth spinal nerve no longer contributes to the innervation of the limb and that limbs in this position exhibit still greater imperfection of function (table 2, series AS4).

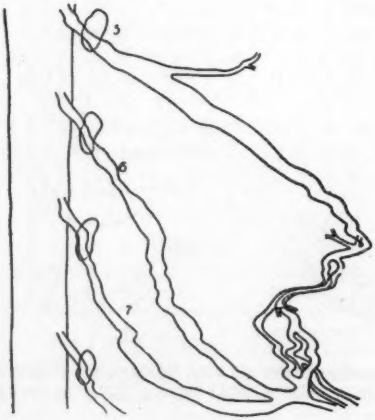

FIG. 2. GRAPHIC RECONSTRUCTION OF THE RIGHT BRACHIAL PLEXUS OF CASE AS4[26], SHOWING THE SEGMENTAL NERVE SUPPLY TO THE RIGHT ANTERIOR LIMB TRANSPLANTED THE DISTANCE OF 4 SEGMENTS POSTERIOR TO THE NORMAL POSITION. × 20

In the series AS5 in which the limbs were implanted the distance of five segments posterior to the normal position, there occurred only one case of those studied (case AS5[26], table 2) in which the limb received innervation from the fifth spinal nerve, the remainder being innervated by nerves posterior to the normal brachial nerves. With this general failure of the limbs in this position to receive innervation from the normal brachial nerves, it is found that still greater restrictions are placed upon their movements, there being only four cases in thirty which functioned normally (table 1 A).

In the series AS6 in which the limbs are so far removed that they receive no contribution from the normal limb nerves nor from the

sixth and seventh nerves, there are no cases which function normally, forty eight per cent being totally incapable of movements and fifty one per cent showing only greatly impaired movements (table 1 A and table 2).

Inasmuch as there are practically no structural deficiencies within the transplanted limb itself, the gradual decrease in the function of the limbs, as they are implanted more and more remote from the normal region, suggests the following possible factors as conditioning their degree of function, (a) structural deficiencies in the shoulder girdle, (b) deficiencies in the shoulder musculature, (c) the failure of certain of the shoulder muscles to receive innervation and (d) the absence of proper central neurone connections.

The shoulder girdle being a mosaic (Detwiler[6]), there is considerable variability in the degree of its development in the transplanted position, yet it is found that its development, in general, is no less complete in cases where the limb has been removed a considerable distance from the normal region than in those where the limb has been removed only a short distance. The difference, therefore, in the degree of function of the limbs could hardly be a result of this factor alone. Secondly, a study of the cross section anatomy of the shoulder region of the transplanted limbs shows that shoulder muscle differentiation does not become less complete as the limbs are implanted more and more posteriorly. No cases have been found in which there was complete absence of any of the muscles which typically develop in the heterotopic position.

Thirdly, peripheral efferent innervation to the shoulder muscles, although somewhat less complete quantitatively in the more posterior positions than in cases where the transplanted limb receives segmental nerves from all or a part of the normal limb level of the cord, is no less developed qualitatively, practically all of the individual muscles receiving some nerve fibers. Certainly the degree of defective peripheral innervation could hardly account entirely for the very imperfect movements exhibited by limbs in the series AS5 and AS6 (table 1 A).

The remaining factor viz: defective connections within the central nervous system appears to be the only one which will adequately account for the marked deficiency of function in limbs transplanted so far posteriorly as to be beyond the point where they receive peripheral innervation from the normal limb level of the cord.

Although in normal larvae of this age, the most obvious motor responses to various types of peripheral stimulation consist of total swimming reactions, under certain controlled conditions motor responses

may be almost entirely limited to co-ordinated movements of the limbs. Such responses may be carried out perfectly by the transplanted limbs when their peripheral innervation is derived from the normal limb level of the cord, but the ability of the transplanted limbs to exhibit movements, co-ordinated with the opposite intact limb, decreases markedly when their peripheral innervation is derived from segments well beyond the normal limb level (series AS6).

As has been shown by Herrick[6] we have developed here a central nervous architecture by means of which peripheral sensory stimuli pass through more or less localized ascending sensory tracts from the cord to the medulla (tractus spino-bulbaris), to the midbrain (tractus spino-tectalis) and to the thalmus (tractus spino-thalamicus). These stimuli may become finally discharged into the somatic motor centers of the spinal cord by means of descending tracts such as the tractus thalamo-bulbaris, tractus tecto-bulbaris, the fasciculus longitudinalis medialis and the tractus bulbo-spinalis. According to Herrick the cell bodies of the tractus bulbo-spinalis lie in the general motor tegementum of the medulla and their axones are directed ventrally into the ventral funiculi of the same and the opposite side. It is highly probable that a certain number of these fibers normally develop only as far as the third, fourth and fifth segments of the cord for specific discharge into the normal appendicular somatic motor centers. The fact that transplanted limbs, receiving peripheral innervation from these levels, exhibit movements which are co-ordinated with the opposite intact limb, strongly suggest such a condition. The behavior of limbs innervated mainly from the sixth, seventh and eighth segments of the cord (series AS5) suggests that these descending neurones, which normally end in the limb level, may be induced to continue their growth an additional segment or two to meet the functional demands imposed upon them by the transplanted limb. Their incapacity for further functional regulation is suggested by the loss of co-ordinated function and the greatly impaired movements that are exhibited by limbs of the series AS6, probably none of which receive peripheral innervation from segments of the cord anterior to the eighth.

The increase in the number of cases with total loss of function as the limbs are implanted more and more posteriorly (table 1 A) would also suggest that there occurs a corresponding increased deficiency in the connections of the purely intraspinal correlation neurones.

Additional limbs transplanted respectively three, four and five segments posterior to the normal intact limb of the host (table 1 B), never

attain the completeness of function attained by limbs in the same relative positions with the normal limb extirpated. Although such limbs may be well supplied with peripheral nerves, derived from segments of the cord posterior to the normal limb level, their greatly impaired movements appear to be a consequence of their inadequate supply of central efferent neurones, which run apparently only as far as the normal limb level where they discharge into the somatic motor centers of the normal intact limb.

The generally restricted and non-adaptive movements which these limbs do exhibit upon stimulation are probably effected through more or less imperfectly connected intraspinal, intersegmental correlation neurones of the levels from which peripheral innervation is derived.

A more complete account of the experiments reported in this paper will appear in later publications.

[1] Braus, H., *Morph. Jahrb.*, **35**, 1906.
[2] Banchi, A., *Anat. Anz.*, **28**, 1906.
[3] Gemelli, F. A., *Rev. Pathologia Nervosa Mentale*, **11**, 1906.
[4] Harrison, R. G., *J. Exp. Zool.*, **4**, 1907.
[5] Detwiler, S. R., *Ibid.*, **4**, 1918.
[6] Herrick, C. J., *J. Comp. Neur.*, **24**, 1914.

THE INTERFEROMETRY OF RAPID VIBRATIONS[1] *CHIEFLY IN RELATION TO TELEPHONE CURRENTS*

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Communicated June 13, 1919

1. Introductory.—The preceding apparatus[2] with telescopic or microscopic enlargement of the telephonic vibrations, behaved on the whole so satisfactorily, that it seemed worth while to try a similar design on the interferometer. I was inclined to doubt the feasibility of the plan; but it appeared on trial that the high tension wires actually keep the auxiliary mirrors of the interferometer practically quiet; so that in the absence of alternating current it is not difficult to find the fringes. Tense wires are out of step with the usual laboratory tremors. The system needs no special damping.

The displacement of achromatic fringes due to the induced secondary current is normal to their direction. The objective of the vibration telescope is to oscillate in the direction of the fringes and to

be coupled with the primary current. A full account of the changes of phase and amplitude in any transformer system may then be obtained from the fringe ellipses usually seen in the interferometer.

2. Apparatus. Wide Bifilar.—This is in large measure a modification of the apparatus described heretofore[3] except that special attachments have been added for sharply reaching the resonance tension of the wire. The latter is shown at $d\ e\ e'\ d'$ in figure 1 (front elevation), being the thinnest steel music wire, about 0.023 cm. in diameter. Its ends are wound around the stiff screws b, b', provided with locknuts, and rotating in horizontal short strong rods a, a', attached to stout standards (not shown) fixed to the bed plate A, B of the interferometer. The wire dd' passed around the grooved pulleys w, w', and above the grooved pulley x, carried in a fork and screw stem y. The latter may be raised or lowered by the nut u, which rests upon the massive carriage BB, supported by the slides AA' of the apparatus. Provision must be made (slotted sheath and pins, not shown) to prevent y from turning on its axis. Tension is roughly given to the wire at the screws b, b', and the fine adjustment is thereafter made at the nut u. This worked very satisfactorily.

The vibrator proper cc' is attached at the middle of the wires d, d', and carries the parallel auxiliary mirrors m, m', of the quadratic interferometer. A thin steel umbrella rib seemed well adapted to fulfill the requirements of cc' though a light soft iron tube would have been preferable.

The telephones T and T' are adjustable on special standards, attached to the bed plate (carriage BB) and placed horizontally, one in front and the other toward the rear of the vibrator cc'. It is desirable that one be adjustable on a micrometer screw and spring, so that the distance of the poles of both from cc' may be regulated.

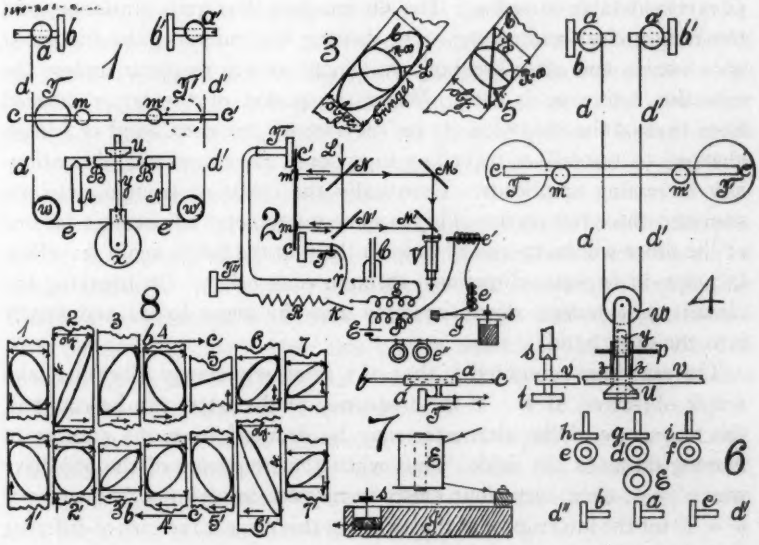
The achromatic fringes in the fine slit image of the telescope field of the interferometer must be observed with a vibration telescope, and it was found desirable to control the latter by a special electromagnet. Figure 2 is a diagram of the parts of the apparatus as a whole, $M\ M'\ N\ N'$ being the mirrors of the interferometer (M' on a normal micrometer screw), m, m' the auxiliary mirrors on the vibrator cc'; T', T, are the telephones (one provided with a switch r), V the vibration telescope, I the mercury interruptor. T'' is an auxiliary telephone for the ear.

The primary consists of the linear coil P described in the preceding paper, the storage cells E (usually four), and the two small electromagnets e, e', for controlling the interruptor and the objective of the

vibration telescope, V. The secondary S was the coil "B" of the preceding paper, wound on glass. This was in circuit with a rheostat R (up to 40000 ohms), the telephones T, T', T'', and the key K. The condenser C in the secondary is available when needed, and the inductive resistance e'' in the primary.

The whole of the parts shown in figure 1 could be slid fore and aft on the carriage BB and AA', to accommodate the interferometer.

3. Observations with the Slit Image.—It will be seen that if an ordinary telescope is used at V, figure 2, the sharp slit image must widen to a band here, as in the preceding apparatus; but the design is much



less sensitive because the rays are parallel throughout. The slit image nevertheless suffices admirably for finding the resonance tension. For this purpose the screw b or b', figure 1, is first manipulated till the image begins to widen. The fine adjustment is then made at u, y, x, till the maximum band-width is reached. One easily recognizes in this way three harmonics, the fundamental at lowest tension and small band-widths; the octave at larger tension with maximum band-width; and the next overtone at still larger tension and diminished band-width. Above this I did not go as the stress on the wire would have been excessive. The reason for the prominence of the octave here, is not

obvious. It does not occur in the later work. While the fundamental showed a band-width of 5 scale-parts, the same for the octave was 42 cm. wide, and for the next harmonic 26 cm. wide.

The remarks made presuppose that the telephones are acting in concert, on opposite sides of the vibrator. We may refer to this as an arrangement in series. When the telephones are acting in opposition, the band-width, s, decreases to one or a few scale-parts, depending on the symmetry of adjustment, etc., which if perfectly made should throw the differential s out entirely.

4. Observations with the Interferometer.—As has been stated the fringes are easily found because the rapid motion of the vibrator implies considerable damping. The slit image is thus quite stationary and the fringes clear and strong. On starting the inductor, the fringes at once vanish and after breaking the circuit slowly reappear, unless the vibration telescope is used. When the period of the latter differed from that of the induction (to be very weak), the even band of fringes changed to wave lines travelling in opposed directions and of continually increasing amplitude. Eventually the crests or troughs only are seen and these but on one side (as some micrometer adjustment for one or the other will be necessary to keep them in the field), again travelling in pairs, in opposite directions, through each other. On breaking the circuit these pulses, slowly coalesce into the wave bands and finally into the even band.

The case here presented is that of a relatively slowly vibrating telescopic objective, at V. If the frequency of the latter can be counted, the frequency of the alternator may be deduced from the number of moving crests in the field. Thus when the frequency of the objective was $n' = 5$, there were four crests in motion, implying a frequency of $n = 20$ for the interruptor of the coil. In this respect the case of different periods is advantageous.

The net double amplitude of the waves measured by the ocular micrometer was about 4 scale-parts and $i = 4 \times 10^{-6}$ amperes came to a scale-part, in case of the present small fringes.

The next step in advance consisted in adding an electromagnet, e; figure 2, at the objective of the vibration telescope V, in series with the electromagnet e of the interruptor, I. The two springs at V and I, moreover, were adjusted to about the same period. The electromagnet e' could be rotated on a vertical axis, so that by moving it closer to or further from the steel spring of V, any degree of band-widths was obtainable in the telescope. Magnificent octave fringes were obtained in this way. They moved merely on opening and closing the circuit.

5. Decreased Bifilar Distances.—The easy accomplishment of the above experiments, where the distance between the bifilar threads was about 30 cm. and their length 60 cm., encouraged me to reduce the distances between the threads until the system was virtually torsional. In such a case the displacement at the ends of the vibrating beam (cc', figure 4) is no longer limited to that of the bifilar wires. Figure 4 is a front elevation of the new apparatus; the steel wires dd' being at a distance of about 6 cm., their length 60 cm., the distance between the auxiliary mirrors m, m', 10 cm., and between the magnets of the telephones T, T', 16 cm. The vibrator cc' was (as above) a steel umbrella rib. The ends of the wires dd' were again wound about the stiff screws b, b' held in posts a, a' rigidly attached to the bed plate of the interferometer (not shown). The wires were stretched below by the pulley w and screw y, controlled by the nut u pressing against the rail v, also rigidly attached to the bed plate of the interferometer. Provision must be made (slotted sheath z and pin p) to prevent y from turning on its axis. A variety of braces are to be introduced to obviate synchronous vibrations of parts of the apparatus.

The adjustment for resonance is here more difficult than in the preceding case, and y must be a fine or a differential screw and the nut u work smoothly. Resonance should first be established by aid of the slit image in a telescope with fixed objective and with small resistance (200 ohms) in circuit. After this a large resistance (10,000 ohms and more) may be inserted and the work continued with the interference fringes when further adjustment is possible.

In a later design of the apparatus, the bar v, rigidly fixed at one end, was elastically controlled at the other end by the fine threaded screw t, pushing against the rigid socket s. This is an excellent fine adjustment and when used does not disturb the fringes.

6. Observations with the New Apparatus.—The first trials were made with the white slit image. Using the coil with a virtual electromotive force of about 0.7 volts and a small resistance (200 ohms), the resonance conditions were easily reached in the well-braced apparatus. The resistance was then increased to 10,000 ohms and the corresponding band-width found. When obtained the band-widths s, persists. The sensitiveness observed if s is 18 scale parts, was $0.7/18 \times 10^{-4} = 4 \times 10^{-6}$ amperes per scale-part (0.01 cm.) of the slit image. Per $\Delta N = 10^{-4}$ cm. of the micrometer of the interferometer, where $b\theta = \Delta N \cos i$ and $\theta = s/2f$ ($f = 23$ cm. being the focal length of the telescope, $b = 10$ cm. the breadth of the ray parallelogram, $i = 45°$), the current would be estimated as 1.3×10^{-7} ampere.

The coil No. 10, with about 90 turns giving 0.001 volts per turn was substituted for B. With the ocular micrometer I obtained 10^{-7} ampere per scale-part. This is less than what was estimated; but a shortage is here inevitable. The fringes used were fairly large, but completely under control.

Unlike the preceding case, the fringes now obtained were of the elliptic type, so that there is unison between interruptor and vibrator. The ellipses were often magnificent. There was little difficulty in measuring their breadth normal to the direction of fringes when quiet, as this is the fringe displacement. On making or breaking the circuit the ellipses oscillate in the well known way, and it may take a part of a minute or more before they subside into the bands (circuit broken). The ellipses remained in the field with resistances up to 10,000 ohms, below which the ΔN micrometer had to be adjusted to bring either axial extremity into view. Notwithstanding the feeble current, the telephone was still quite audible; so that the sensitiveness of the ear has not been exceeded. When the degree of resonance between the telephonic vibrator and the vibrating objective is exceptionally perfect, marked ellipses may appear in the absence of current, in spite of the fact that the telescope has an independent mounting. This very annoying phenomenon is hard to eliminate.

Another smaller coil with but ten turns giving 0.001 volt per turn was installed with the object of ultimately approaching a condition of silence in an audible telephone. The results were striking throughout but can not be given here.

7. *Capacity and Selfinduction in the Secondary.*—The phase differences thus far observed are attributable to the selfinduction of the secondary. It is interesting therefore to test whether the lead due to capacity can be equally well observed. The circuit, figure 2, was therefore provided with a condensor C containing up to one microfarad, in steps of tenths. An auxiliary telephone T'' was also inserted as a detector. The results were successful at once, as shown in figures 3 and 5. In figure 3, $R = \infty$ is the symmetrical ellipse, obtained on open circuit. This changed rapidly into the oblique ellipse C when 0.5 microfarads were inserted, and the latter into the bands L (with a range of 30 scale-parts) when the circuit was closed with about 3000 ohms. In another adjustment (fig. 5) of primary, $R = \infty$ gave normal bands (i.e., the fringes do not vibrate); the capacity 0.5 microfarads now gave the oblique bands C and the selfinduction ($R = 5000$ ohms) the nearly symmetrical ellipse L. Space prevents the insertion of other relevant results.

8. Selfinduction in the Primary.—The present experiments contain an element of uncertainty owing to the mechanical (or possibly magnetic) coupling of the vibrator cc', on the interferometer, figure 2, and the objective of the vibration telescope V. I have not thus far been able to eliminate this. Information was sought by inserting additional self-induction into the primary. The two small electromagnets, figure 2, e'', (about an inch long), which could be used either separately or in series, were available for this purpose.

The different elements of harmonic motion involved in the experiment may be analyzed as follows. The whole is fundamentally subject to the vibration period of the spring at the interruptor of the primary, which gives the impressed electromotive force

$$l = l_0 \sin \omega t \tag{1}$$

The current induced in the primary controls the objective of the vibration telescope, which thus moves with a lag α subject to

$$i = i_0 \sin (\omega t - \alpha) \tag{2}$$

and this may be modified by the resistance and inductance in the primary.

The objective is as stated either mechanically or magnetically coupled with the vibrator on the interferometer in a way yet to be ascertained; for each has an independent mounting. Hence the vibrator displacements s are subject to an equation with a lag or lead

$$s = s_0 \sin (\omega t - \beta) \tag{3}$$

in the absence of current in the secondary ($R = \infty$).

Finally the secondary, if carrying current has its own lag or lead γ depending on the R, L, C there inserted, and is thus subject to an equation

$$s = s_0 \sin (\omega t - \gamma) \tag{4}$$

where γ is essentially associated with β, as seen in the preceding paragraphs.

If we suppose the coupling implied in equation (3) to be uniform, the lag in equation (2) may be made obvious.

In these experiments the vibration figures were very large and very definite in the successions of their changes with L, however frequently repeated; but unfortunately the induction in the secondary is soon quenched.

9. Direct Telephonic Induction.—The influence of the oscillating magnetic field on the telephone is much more pervasive than one is apt to

suppose. The effect moreover is particularly marked if the telephone is open, i.e. with no connection between the clamps. The stray vibrating field produced by a small electromagnet (say ¼ inch iron, 2 inches long) is thus quite audible even beyond 50 cm. from the electromagnet. The degree of response depends moreover on the orientation (fig. 6) of the telephone relative to the electromagnet E. If we take the three cardinal positions of the plane of the coil or the diaphragm, the vertical positions e, d, f, and the fore and aft horizontal positions h, g, i, have their maximum response in the plane of symmetry $g\,d\,E$. The right and left horizontal positions d'', b, a, c, d', give minimum response (telephone silent) in this plane (E, a), with maxima at symmetrical positions, b and c. A convenient reversal of magnetic field is thus obtained.

Although all telephones show the phenomenon pretty well, since it is more distinct on open circuit (which implies a current oscillating from damp to clamp) it would be well worth while to wind a telephonic bobbin provided with a capacity for the particular purpose of catching the stray magnetic field, such as is here encountered. Without proceeding to this extent, I used the telephone as a secondary as shown in figure 7, where E is the electromagnet of the interruptor I, s being the vibrating break circuit spring. The telephone depending adjustably from the sleeve a may be slid right and left or rotated into any horizontal position relative to E, and the current obtained measured by the vibrator.

In the endeavor to minimize the mechanical coupling, the telescope (separately mounted) was placed at about a meter from the vibrator. In this case the phase difference of the vibrations of fringes and objective was annulled, but the bands in the absence of current were nevertheless somewhat oblique to the direction of the vibration of the objective, showing that the fringes still vibrated.

With this exception the behavior of the telephone inductor was admirable. In passing from the positions b to c by sliding the telephone, the ellipses regularly passed through the oblique bands, indicating that these successive ellipses, even if of nearly equal size, were opposite in their phase rotation. This was the case when the secondary was closed with 5000 ohms and the inevitable inductance; also when a capacity was placed in the secondary and finally on passing from an inductance to a capacity in the secondary. The effect produced by changes of capacity of 0.5 microfarad was marked. The alternate-current effect, moreover, was still apparent when the circuit was closed with 25,000 ohms and the telephone practically silent.

The most direct criterion as to changes of phase is the rotation of ellipses as indicated in figure 8. I shall give a few examples of what is observed in the telephone displacement in question.

In the absence of current the fringe bands were nearly horizontal parallel lines. The secondary was closed with 5000 ohms and the inductance of the three telephones. From the position *b* (ellipse 1, figure 8 quiescent) the inductor telephone was quickly displaced to position *c*. The enormously eccentric, finally linear ellipse, 2, follows, which then rotates and contracts counterclockwise through the figures 3 and 4 into the sharp bands (usually but not always) no. 5. These duplications then separate on further rotation into the final quiescent form, 7. The arrows indicate the drift of one of the four points of tangency. On returning from *c*, by quickly sliding the telephone inductor into the position *b*, the figures roll clockwise from 7′ to 1′. Number 7′ passes at once through the highly eccentric ellipse 6′, though in other slower adjustments intermediate sharp duplicates like 5 may be detected between 6′ and 7′. The stretched ellipses, which follow immediately after the change of aspect of the telephone bobbin to the magnetic lines, are noteworthy. They result from the sudden reversal of the magnetic field in spite of the vibration. Ellipses cross over or change sign of rotation at 2 and 6′, but not near 3′ or between 5, the latter being oscillations. The corresponding cases for capacity, were similar on the whole, though less pronounced. Moreover the first and final forms were not quite in opposed phases.

10. Narrow bifilar.—After obtaining the favorable results just described, it seemed obvious that the sensitiveness could be further increased by diminishing the distance between the bifilar wires. Accordingly, with the same inductor, figure 4, the above wires (diameter 0.023 cm.) were adjusted at but 1.5 cm. apart by decreasing the diameter of the lower pulley. A few other modifications were added. The results however were disappointing throughout.

A final observation may be added. The auxiliary audible telephone responded with about equal loudness when the telephone circuit was closed with 400 ohms and when a condenser of 1 microfarad capacity was inserted. But the vibrator reacted in the former case (resistance and selfinduction) with a deflection of 23 scale-parts, whereas in the latter (capacity) the response was at most 2 scale-parts; and this required a slightly different tension of wire. The metallically closed circuit therefore affected the vibrator at least 12 times more strongly than the oscillation due to the capacity of 1 microfarad. Small capaci-

ties like 0.1 microfarad fail to influence the vibrator though to the ear the sound is quite loud. The capacity should have to be increased to 10 or 20 microfarads for equal effects on telephone and vibrator. In another experiment the closed circuit gave 20 scale-parts. The insertion of 4 microfarads decreased this to 4 scale-parts, which is again a demand of about 20 microfarads for an equality of behavior. On the other hand, while the telephone responds for a phenomenally small capacity, it soon ceases to increase in loudness (for 1, 2, 3, 4, mf., or resistances), whereas the deflections of the vibrator increase regularly.

[1] Advance note from a Report to the Carnegie Institution of Washington, D. C.
[2] These PROCEEDINGS, **5**, 211–217, (1919).
[3] These PROCEEDINGS, **4**, 328–333, (1918). Carneg. Publ. No. 249, **3**, 1919, chap. v.

ON THE PRESSURE VARIATION OF SPECIFIC HEAT OF LIQUIDS

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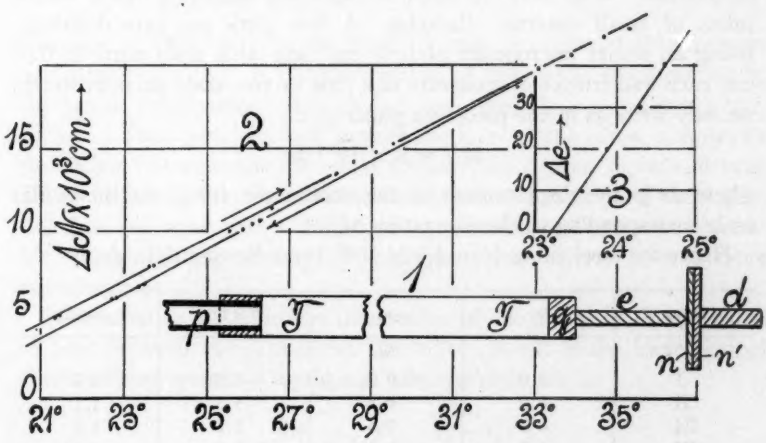
1. Introductory.—The measurement of the specific heat of a liquid in its relation to pressure is surrounded by so many difficulties, that any method which gives a fair promise of success deserves to be carefully scrutinized. During the course of my recent work on interferometry, I have had this in view, and the plan which the present paper proposes is particularly interesting as it seems to be quite selfcontained.

2. Equations.—If θ, p, ρ, c, denote the absolute temperature, the pressure, the density, and the specific heat at constant pressure, respectively, of the liquid, and if $\alpha' = (dv/v)/d\theta$ is its coefficient of volume expansion, the relation of these quantities may be expressed by the well known thermodynamic equation

$$d\theta/dp = \alpha'\theta/J\rho c \qquad (1)$$

where J is the mechanical equivalent of heat, and the transformation is along an adiabatic. The main difficulty involved would therefore be the measurement of the temperature increment; for dp could be read off on a Bourdon gauge after a partial stroke of the lever of my screw compressor, with facility. It is my purpose to find $d\theta$ by the displacement interferometer. To fix the ideas; suppose the liquid in

question is introduced into a long steel tube TT, figure 1, and that the tubulure p conveys the increments of pressure dp. The end p is rigidly fixed. The other end q of the tube is free to move. By aid of the stylus, e, the elongation is registered on the plate n of a contact lever read by interferometry, the lever being identical in construction with the apparatus described in my paper on magnetic elongation.[1] Thus the interferometer will indicate the elongations due both to the pressure increment and to the corresponding temperature increment of the suddenly compressed liquid, and it becomes a question to what degree the two may be adequately separated. If Δl, Δp, $\Delta\theta$ are corresponding increments of the length, l, of the tube and the



pressure and temperature of its liquid content, we may write successively, if $\Delta l = \Delta l' + \Delta l''$,

$$\Delta l'/l = (r_1^2/3k(r_2^2 - r_1^2))\,\Delta p = \beta\Delta p, \text{ say,} \tag{2}$$

$$\Delta l''/l = \alpha\Delta\theta \tag{3}$$

where α is the coefficient of expansion, k the bulk modulus, r_1 and r_2 the internal and external radius of the steel tube of length l. Hence

$$\alpha\Delta\theta = \Delta l/l - \beta\Delta p \tag{4}$$

and equation (1) becomes

$$d\theta/dp = \frac{\Delta l/(l\Delta p) - \beta}{\alpha} = \frac{\alpha'\theta}{J\rho c} \tag{5}$$

or

$$c = (\alpha'\theta/J\rho)\,(\alpha/(\Delta l/(l\Delta p) - \beta) \tag{6}$$

Hence c may be found from observations of Δl and Δp, provided α' and ρ, α and β are sufficiently known.

3. Measurement of the Pressure Coefficient β.—For this purpose the tube TT, figure 1, is placed in a water jacket of constant temperature, and β found by internal pressure, directly. Experiments of this kind were contributed with some detail in an earlier paper.[2] The method then used consisted in finding β from the displacement of the spectrum ellipses under known conditions; but the present method of the contact lever and achromatic fringes may be considered preferable, particularly if the tube contains water, for which the thermal discrepancy is small.

Moreover, since $\Delta\theta$ is primarily aimed at, β should be made as small as possible. This may be done by selecting relatively thick walled tubes of small external diameter. A few data are here desirable. Using an ocular micrometer plate 1 cm. long with scale parts of 0.01 cm. each and fringes of moderate size (one or two scale parts in width) we may write as in the preceding paper (l. c.)

$$\Delta l/l = 3 \times 10^{-7}\, \Delta e \qquad (7)$$

where Δe is the displacement of the achromatic fringe on the ocular scale corresponding to the elongation $\Delta l/l$.

Hence for steel tubes ($k = 1.8 \times 10^{12}$) the following data apply

TUBES	$2r_1$	$2r_2$	$\beta \times 10^7$	$\Delta e'/\Delta p$
	cm.	cm.		
I	1.0	0.9	8.0	2.7
II	1.0	0.8	3.3	1.1
III	0.7	0.6	5.2	1.7
IV	0.7	0.5	1.9	0.63

β being reckoned per atmosphere.

4. Measurement of α.—For this purpose the tube TT is to be clean and empty, the nozzle p removed and a long-stemmed thermometer passed from end to end of the tube, through the end p. Externally the tube is surrounded by a coil of wire for electric heating and appropriately jacketed. Measurements made in this way with a brass tube are given in figures 2 and 3 and they would have been quite satisfactory if the tube had been properly protected from loss by radiation. (ΔN is read off on the displacement micrometer at an interferometer mirror; Δe in the ocular scale).

If for the steel tube, $\alpha = 10^{-5} \times 12$, equations (3) and (6) then give us

$$\Delta\theta = 0.025\, \Delta e$$

or about 40 scale parts of the ocular micrometer per degree of temperature.

5. Liquids.—It remains to select suitable liquids for experiment. For water at 27°, $d\theta/dp = 0.0019$; for ethylic alcohol at about 18°, $d\theta/dp = 0.017$; for ether at 18°, $d\theta/dp = 0.028$, pressures being measured in atmospheres. Thus for the four tubes specified in §3, the respective displacements in the ocular micrometer would be (per atmosphere)

I	$\Delta e' = 2.7$	water:	$\Delta e'' = 0.08$
II	1.1	alcohol	$\Delta e'' = 0.68$
III	1.7	ether	$\Delta e'' = 1.14$
IV	0.63		

The case of water may be dismissed for here the thermal displacement per atmosphere, $\Delta e''$, is a small fraction of the elastic displacement in the ocular micrometer. But alcohol and ether show satisfactory conditions. Thus a sudden half turn of the lever of the screw compressor producing 100 atmospheres would displace the fringes, in case of tube III and ether, 173 scale parts elastically and 114 scale parts thermally, together 287 scale parts. Stops of 30 atmospheres would be advisable. Tube IV with 63 and 114 scale parts respectively is even more advantageous.

It remains to estimate the diminution of $\Delta\theta$ owing to the partition of heat between the liquid and the tube. If $\Delta\theta'$ is the increment of the combined system of liquid and tube the ratio will be

$$x = \frac{\Delta\theta'}{\Delta\theta} = 1/\left(1 + \frac{r_2^2 - r_1^2}{r_1^2}\frac{c'\rho'}{c\rho}\right)$$

if c' and ρ' are the specific heat and density of the solid. These ratios x for the tubes and liquids in §3 and the corrected $\Delta e''$ are easily tabulated. Tubes of the type I are unsatisfactory. In case of tubes of the types II or III the thermal displacement would be but about 5% of the elastic displacement in case of water; but in case of alcohol 25 to 35%, and of ether 35 to 55%. In tubes of the type IV the advantages of thicker walls and small external diameter have again decreased. The problem of selecting the best tube admits of general solution.

If we combine equations (4) and (8) and put

$$A = \Delta l/l; \quad B = \Delta p/3k; \quad C = \rho' c'/\rho c; \quad y = r_2^2 - r_1^2/r_1^2$$

the result is

$$\alpha\Delta\theta' = \frac{A - B/y}{1 + Cy} \tag{9}$$

Here y is the ratio of solid and liquid sections and we inquire what value of y will make $\Delta\theta'$ a maximum provided A, B, C are constant. If the thermal and elastic elongations are to be equal $A = 2B$. Differentiating (9) and reducing:

$$1/y = C(\sqrt{1 + A/BC} - 1) \tag{10}$$

and since y must be positive the radical is positive. Now if $A = 2B$, for example, the ratio of diameters $2r_1$ to $2r_2$ would in all cases have to exceed 0.65. If $A = 3B$, the case of water remains nearly the same, but for ether and alcohol the diameter ratio approaches 0.9.

[1] These PROCEEDINGS, 5, 1919, (267–272).
[2] Carnegie Publ. No. 249, 1917, pp. 84–94.

STUDIES OF MAGNITUDES IN STAR CLUSTERS, IX. THE DISTANCES AND DISTRIBUTION OF SEVENTY OPEN CLUSTERS

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The question of whether globular clusters are really or only apparently absent from the mid-galactic segment makes the study of the distances of open clusters particularly important. These objects are relatively near to the galactic circle, and many appear to be at such great distances along the plane as to support the hypothesis that obstructing matter is insufficient to occlude globular clusters in mid-galactic regions.[1] On the other hand there is evidence that globular clusters actually may not be absent from low galactic latitude,[2] and the following discussion of open clusters and other relevant factors suggests that the question must be considered an unsettled one for the time being.

Although the question of the reality of the region of avoidance affects but little the general conclusions reached in earlier papers regarding globular clusters, spiral nebulae, and the Galaxy, two modifications should be made to previously suggested interpretations,[3] in case we demonstrate the existence of much obstructing matter along the galactic

plane beyond the confines of the local cluster: First, the distance of the center of the system and the total extent of the Galaxy may be considerably greater than inferred from the visible globular clusters; second, the transition from globular to open clusters, if there be such an evolution,[4] is not necessarily rapid and inevitable when the globular clusters enter thickly populated galactic regions.[5] It should be noted that the diameter-parallax correlations[6] are some insurance that a hypothetical *partial* obstruction has exaggerated neither the distances of globular clusters nor the galactic dimensions. If dark clouds obscure distant globular clusters they are remarkably thorough (except in one or two possible cases[7]), the obscuration at any point appearing to be absolute or non-existent. According to the magnitude results now available for faint galactic stars, the obstructing clouds also are of such character that they do not affect star colors appreciably.

Several years ago the correlation of the apparent diameter to the brightness of stars in open clusters was pointed out and the possibility noted of obtaining relative parallaxes from measures of magnitude or diameter.[8] My values of the relative parallaxes of these open groups, however, as well as the provisional absolute values, have remained unpublished in the hope that the accumulation of data on magnitudes and spectra would permit the determination of more definite absolute parallaxes. The open clusters contain few, if any, Cepheid variables, and appear almost without exception to be quite beyond the reach of direct measures of distance. Parallaxes of an accuracy comparable with that for globular clusters seem unattainable; but, notwithstanding some uncertainty in diameters due to looseness of structure and to intermixture with the Milky Way stars among which the open clusters usually lie, it appears quite possible to use their angular dimensions to determine a system of relative distances and to use the apparent magnitudes of the red giants or the B-type stars in as many clusters as possible to establish the scale and zero point for absolute distances.

My observational work on open clusters comprises: (1) Thirty spectrograms of some 200 faint stars in various northern groups, made with a slitless spectrograph of small dispersion at the 80-foot focus of the 60-inch reflector; (2) more than a hundred direct photographs at the primary focus of the 60-inch; (3) the determination of magnitudes and colors of about two thousand stars; (4) the measurement of the diameters and form of all known open clusters on Franklin-Adams charts, Harvard photographs, or Mount Wilson plates. This work has been supplemented by similar data from other sources, chiefly from the

observations at Harvard on the spectra in a few bright clusters[9] and from the work of Adams and van Maanen on the double cluster in Perseus.[10]

The accompanying table contains the parallaxes and space coördinates of the 70 open groups which are sufficiently rich, condensed, symmetrical, and distinct from the background to make practicable the use of diameter as a criterion of distance. Melotte's well-known catalogue[11] of clusters contains more than twice as many open groups as are listed here, but a large number of his clusters are so ill-defined and poor in numbers that they appear to be little else than chance groupings of Milky Way stars. The omission of these irregular and scattered aggregations does not operate selectively in matters of distance or distribution.

The first column of the table contains the number of the cluster in Dreyer's *New General Catalogue* or its indices. A few that are not listed by Dreyer retain their numbers in Melotte's catalogue. Parallaxes of the fourteen clusters marked with an asterisk have been derived directly from measured apparent magnitudes combined with absolute magnitudes estimated on the basis of observed colors, or spectra, or both. The adopted mean absolute magnitudes of early type stars depend on the studies of Kapteyn,[12] Plummer,[13] and Charlier,[14] and on my own results for the luminosities of blue stars in globular clusters. Apparently without exception the brightest stars in open clusters (as in globular clusters) are giants in luminosity.

By using the measured diameters and adopted distances of these specially studied clusters to determine a parallax-diameter curve, the parallaxes of the other open clusters have been estimated on the basis of diameters alone; in most cases, however, the relative distances have been roughly checked with the aid of the magnitudes of the brightest stars as estimated by Bailey[15] or as derived from Mount Wilson photographs. The diameters are the means of measures by Bailey, Melotte, Shapley, and Miss Davis. In keeping with the probable accuracy, most of the parallaxes have been rounded off to a single significant figure after computing the linear galactic coördinates, which are given in the fourth and fifth columns. The very largest parallaxes are uncertain because of the lack of precision in the corresponding end of the parallax-diameter curve; the very smallest are uncertain because of the large effect of small errors in measurement of diameter; most of the diameters, however, fall within limits for which the curve is well-defined and for which the measures of diameter by the four observers are

in good agreement. It is expected that the measures and computations underlying this work and a more complete discussion will appear in a *Mount Wilson Contribution*.

POSITIONS IN SPACE OF SEVENTY OPEN CLUSTERS

N. G. C.	GALACTIC LONGITUDE	PARALLAX	DISTANCE (UNIT 100 PARSECS		N. G. C.	GALACTIC LONGITUDE	PARALLAX	DISTANCE (UNIT 100 PARSECS	
			Along plane	From plane				Along plane	From plane
457	93°	0.00016	62	− 5.3	2682*	183°	0.00025	34	+22.0
663	97	0.0002	50	− 1.2	I. C. 2488	245	0.0002:	43	− 2.7
869*	102	0.0008	12	− 0.9	3114	250	0.001:	10	− 0.5
884*	103	0.0008	12	− 0.8	3532†	257	0.002:	4	+ 0.1
1039	111	0.0006	17	− 5.0	I. C. 2714	259	0.0002	59	− 1.2
1245	114	0.0002	44	− 7.1	Mel 105	260	0.00007	140	− 4.7
Pleiades*	134	0.015	0.6	− 0.3	Mel 108	262	0.0001	90	+10.5
1528	119	0.0004	24	0.0	4349	267	0.00025	40	+ 1.0
1807	154	0.0002	42	− 9.7	5281	277	0.00007	140	− 0.4
1912*	139	0.0003	32	+ 0.6	5617	282	0.0002	50	+ 0.2
1960*	142	0.0002	48	+ 1.1	5823	289	0.00015	67	+ 3.3
2099*	145	0.0004	26	+ 1.5	5999	293	0.0001	100	− 3.5
2168*	154	0.0006:	18	+ 0.8	6005	293	0.00006	160	− 9.2
2266	154	0.00009	110	+20.0	6067	297	0.0002	45	− 1.7
2287	199	0.0006:	16	− 2.6	6124	308	0.0005	21	+ 2.2
2323*	189	0.0002	50	− 0.4	6134	302	0.00014	71	− 0.1
2324	181	0.0001	91	+ 6.4	6192	308	0.0001	83	+ 3.2
2355	170	0.0001	98	+22.0	6222	309	0.00007	140	− 0.4
2360	197	0.00014	71	− 0.8	6242	313	0.00014	71	+ 2.8
2421	204	0.0001	77	+ 1.2	6259	310	0.0002	53	− 1.5
2420	165	0.0001	94	+34.0	I. C. 4651	308	0.0002	50	− 7.0
2423	199	0.0003	34	+ 2.7	6405*	324	0.001:	8	− 0.1
Mel 71	197	0.0001	77	+ 7.8	6451	327	0.00009	110	− 3.9
2439	214	0.0001	91	− 5.7	6475*	323	0.003:	4	− 0.3
2437	200	0.0005	21	+ 1.8	6494	338	0.0005	21	+ 0.8
2447	208	0.0002	43	+ 1.0	6520	330	0.00009	110	− 6.2
2477	221	0.0005	20	− 1.8	6603	340	0.00008	120	− 3.8
2489	214	0.0001	100	+ 0.3	Mel 204	341	0.0006:	16	− 1.5
2506	198	0.0001	98	+19.0	6645	343	0.0002	56	− 4.2
2516	241	0.002:	6	− 1.5	6705*	355	0.00014	71	− 4.2
2539	201	0.0003	31	+ 6.8	6709	10	0.0002	56	+ 3.8
2548	195	0.0007:	14	+ 4.2	6834	33	0.00008	120	+ 0.9
2567	217	0.0001	83	+ 5.5	6838*	24	0.00007	140	−14.0
2627	219	0.0001	90	+12.0	7654	80	0.00016	62	− 0.2
2632*	172	0.003:	25	+ 1.6	7789	83	0.0003	37	− 3.7

† The bright southern cluster N.G.C. 3532 is conspicuously elliptical.

The well-known concentration of open clusters in the Milky Way is shown by the smallness of the tabular distances from the plane. This condition allows a good representation of the distribution in space

simply through plotting (as in figure 1) the galactic longitude and the distance projected on the galactic plane. No striking lack of symmetry appears in this diagram, except the almost total absence of bright open clusters in the first 90° of galactic longitude.

The mean distance of the 70 open clusters along the plane is 5900 parsecs, all individual values (except for the Pleiades) lying between 400 and 16,000 parsecs. By taking the dip of the central line of the Milky Way[16] as 1°, and the distance of the sun above the plane as 60 parsecs,[17] the distance of the stars and star clouds that enter Newcomb's

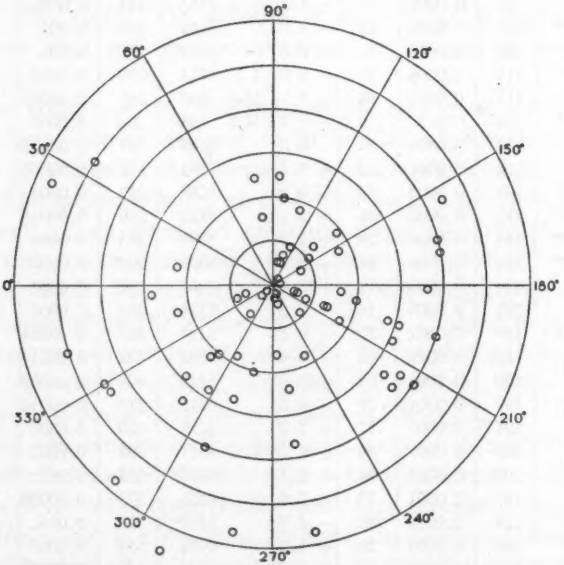

FIG. 1. DISTRIBUTION OF OPEN CLUSTERS IN THE GALACTIC PLANE
The direction angles are galactic longitudes; the annuli are 25,000 parsecs in width

(visual) determination of the position of the galactic circle is of the order of 60/sin 1° = 3500 parsecs. Although the uncertainty of this value is large, it seems reasonable to infer that the open clusters are intermingled with the non-cluster stars of the galactic stratum.

The diagram in figure 2 illustrates, for all the open clusters, globular clusters, and Cepheid variables falling between galactic longitudes 290° and 360°, the distances projected on the galactic plane plotted as abscissae against the distances from the plane as ordinates. This region of the sky, containing the great Milky Way clouds of Ophiuchus,

Sagittarius, and Scorpio, is symmetrical about the point that is indicated by the distribution of globular clusters as the center of the galactic system. It is mainly the absence of globular clusters from low galactic latitudes throughout this interval of 70° in longitude that gives rise to the phenomenon of a region of avoidance. The diagram shows that the distribution of stellar material is probably fairly continuous along the galactic plane; from the local cluster the Cepheid variables (and various other types of highly luminous galactic stars) extend to the nearer star clouds and open clusters, and the latter are recorded among the more distant star clouds along the plane nearly as far as the center of the system of globular clusters.

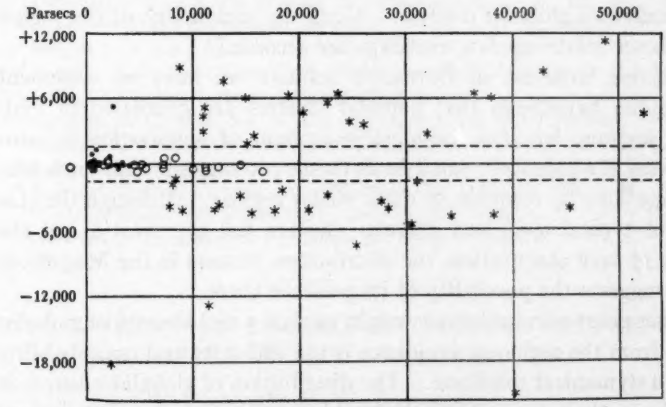

FIG. 2. DISTRIBUTION OF THE GLOBULAR CLUSTERS (ASTERISKS), OPEN CLUSTERS (OPEN CIRCLES), AND CEPHEID VARIABLES (DOTS) THAT FALL BETWEEN GALACTIC LONGITUDE 290° AND 360°

Ordinates are distances from the galactic plane; abscissae are distances along the plane

If, as appears very probable, the system of globular clusters outlines the galactic system, why do we not find large numbers of open clusters in the vicinity of and beyond the center, between the two halves of the assemblage of globular clusters? Nearer the sun there are some 70 open groups within the mid-galactic segment—the segment which appears to be their natural and only domain. Is the distant central region that is devoid of globular clusters also in part avoided either actually or apparently by open clusters? The observed scarcity of open clusters in this direction leads us to question the reality of the avoidance; it may be that patches of obscuring material conceal both open and globular clusters, as well as many of the more distant stars,

perhaps thus playing a large part in the conspicuous rifts in the Milky Way.

Barnard's dark markings, recently catalogued,[18] do not furnish direct evidence of this obscuration, for, singularly enough, more than half of his objects fall outside the region of avoidance, if we exclude one small region near Messier 11 for which 30 separate positions are listed. It appears that most of the markings may be affiliated with the local cluster, and at no great distance from the sun. Thus in the Taurus-Orion region, two-thirds of the dark markings have negative galactic latitudes, lying on the average more than 10° south of the galactic circle; in the opposite region the latitudes are largely positive, the dark markings in Ophiuchus and Scorpio lying intermingled with the seemingly unaffected globular clusters. Along the middle li[illegible] of the region of avoidance relatively few markings are recorded.

Indirectly, however, in Barnard's nebulae we have an argument favoring the hypothesis that globular clusters are concealed in mid-galactic regions, for, if a considerable amount of obscuration is associated with the relatively small local cluster, it suggests that such material may also be common in other stellar regions. Although the star counts in typical open and globular clusters fail to reveal as yet the presence of such obscuration, the distribution of stars in the Magellanic Clouds suggests the possibility of its presence there.

Another point of considerable weight against a real absence of globular clusters from the region of avoidance is the difficulty and improbability of such a dynamical condition. The distribution of globular clusters in space shows their very close relationship to the Galaxy; the average velocity and probable mass both appear to be very great; the possibility, therefore, of repelling a globular cluster from the stellar stratum, or completely transforming it during a single passage, seems remote. From a gravitational standpoint we should naturally expect the frequency of clusters to be greatest at or near the galactic plane, and that many oscillations must occur before the hypothetical assimilation and transformation is completed for an average globular cluster.

Of the several arguments favoring the reality of the empty zone, we recall that the most important are the completeness of the observed absence at all distances from the sun, and the various suggestions of immediate genetic relationship between the external globular clusters and the open clusters within, including the observation that the globular clusters nearest the plane appear to be the most open.

[1] Shapley, Harlow, *Mt. Wilson Contr.*, No. 152, 1917 (1–28), pp. 22, 23 and footnotes; No. 157, 1918 (1–26), p. 10; No. 161, 1918 (1–35), sections I, II, and III.

[2] *Ibid.*, No. 157, 1918 (1–26), p. 12; No. 161, 1918 (1–35), section IV.

[3] *Ibid.*, No. 157, 1918 (1–26); No. 161, 1918 (1–35), sections VII and VIII.

[4] *Ibid.*, No. 161, 1918 (1–35), section VIII; No. 157, 1918 (1–26), pp. 12–14.

[5] But whether the absence of clusters is real or only apparent, we must remember that the assignment of a definite thickness of three or four thousand parsecs to the galactic segment is mostly a matter of convenience and approximation; the intention is merely to suggest that practically every known object except spiral nebulae and globular clusters is within a thousand parsecs or so of the central plane of a greatly extended, indefinitely bounded stellar stratum.

[6] Shapley, Harlow, *Mt. Wilson Contr.*, No. 152, 1917 (1–28), fig. 1; No. 161, 1918 (1–35), section V.

[7] *Ibid.*, No. 152, 1917 (1–28), p. 22, footnote 2.

[8] *Ibid.*, No. 115, 1915 (1–21), p. 11 and fig. 1.

[9] Pickering, E. C., *Ann. Obs. Harvard Coll., Cambridge, Mass.*, **26**, 1891 (260–286).

[10] Adams, W. S., and van Maanen, A., *Astr. J. Albany, N. Y.*, **27**, 1913, p. 187.

[11] Melotte, P. J., *Mem. R. Astr. Soc., London*, **60**, 1915 (175–186).

[12] Kapteyn, J. C., *Mt. Wilson Contr.*, Nos. 82 and 147, *Astrophys. J., Chicago, Ill.*, **40**, 1914 (43–126), **47**, 1918 (104–133, 146–178, 255–282).

[13] Plummer, H. C., *Mon. Not. R. Astr. Soc., London*, **73**, 1913 (174–191).

[14] Charlier, C. V. L., *Meddelanden Lunds Astr. Obs., Lund*, Series 2, No. 14, 1916 (1–108).

[15] Bailey, S. I., *Ann. Obs. Harvard Coll., Cambridge, Mass.*, **60**, 1908, No. VIII.

[16] Newcomb, S., *Pub. Carnegie Inst., Washington, D. C.*, No. 10, 1904 (1–32).

[17] Shapley, Harlow, *Mt. Wilson Contr.*, No. 157, 1918 (1–26), p. 23.

[18] Barnard, E. E., *Astrophys. J., Chicago, Ill.*, **49**, 1919 (1–23).

A COMPARISON OF CERTAIN ELECTRICAL PROPERTIES OF ORDINARY AND URANIUM LEAD

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Communicated, June 17, 1919

A comparison of the physical properties of chemical isotopes is of significance because of the light it may throw on the corresponding mechanisms. Comparisons of the properties of ordinary and uranium lead have hitherto been made with respect to the atomic volume,[1] thermoelectric quality,[2] and emission spectra.[3] No differences have been detected, except possibly a very slight shift in one of the spectrum lines. It is not to be expected that large differences exist with regard to other physical properties, but nevertheless a verification by direct experiment is not without interest.

Through the kindness of Prof. T. W. Richards there was made available for me 20 grams of lead of radio-active origin on which he has already published chemical data,[4] and also a similar quantity of puri-

fied ordinary lead. The radio-active lead was from Australian carnotite, and showed an atomic weight of 206.34, which is therefore 0.41% lower than that of ordinary lead. The theoretical and experimental value for the atomic weight of the pure end product of the disintegration of uranium is 206.08, so that this sample was probably composed of 76% pure isotope and 24% ordinary lead. The radio-active lead contained not over 5 parts in 100,000 of impurity, mostly silver, and the ordinary lead was a trifle less pure, showing also a trace of copper. For the experiments both these samples were formed into wire 0.035 cm. in diameter by cold extrusion through a steel die. The samples were cast into ingots ready for extrusion by Professor Richards, who melted them in hydrogen and then continued the fusion for ten minutes in vacuum.

The measurements recorded here are comparisons of the pressure coefficient of electrical resistance, temperature coefficient of resistance, and specific resistance. The comparison of pressure coefficient of electrical resistance was made with more accuracy than the other measurements because a specially adapted apparatus designed for another purpose was available.

In order to compare the pressure coefficients, approximately equal lengths of the two varieties of lead were wound non-inductively on either end of a bone core, which was placed in the pressure chamber. The two terminals of each wire were soldered to independent leads which were brought through the walls of the pressure chamber through an insulating plug of a design essentially like that previously described,[5] except that there were three, instead of one, insulated stems through the plug. The two wires were made the two extension coils of a Carey Foster bridge. In this way the difference of the pressure effects on the two coils could be measured. The absolute value of the pressure effect on ordinary lead had been previously determined with sufficient accuracy.[6] The apparatus for producing pressure was the same as that previously described.[5]

Readings were made to 12,000 kgm./cm.^{2} at 1000 kgm. intervals, with increasing and decreasing pressure, and at two temperatures, 25° and 85°. An independent set of readings was made to determine the effect of pressure on the resistance of the leads, which turned out to be almost negligible. At 25° the decreases of resistance of the two kinds of lead under 12,000 kgm. were the same within 0.02% of the total decrease, and at 85° within 0.03%. Assuming that the possible error in reading the slider settings of the Carey Foster bridge was 0.1 mm. and that the errors conspired in the most unfavorable way, the possible

instrumental error in the readings would have been 0.04%. The agreement is therefore as close as could be expected. At pressures lower than 12,000 the agreement of the readings was also always within possible instrumental errors.

The temperature coefficients were compared by comparing the resistances at atmospheric pressure at 25° and 85°, while still wound on the same bone core as was used for the pressure measurements. Over this range the temperature coefficients differed by 0.06% of themselves. This is slightly greater than the possible instrumental error, but is less than possible discrepancies due to differences of handling which I have previously found in different lengths from the same sample of ordinary lead.

The specific resistances were compared by comparing the actual resistances of the samples already measured. Correction for inequalities of dimensions was made by measuring the length of each sample and its weight, and from these computing the average cross section assuming that the densities were directly proportional to the atomic weights.[1] In order to measure the length, the wire had to be cut from the core, unwound, and straightened. Because of the mechanical softness of lead, this is a difficult operation without error, so that the comparison of specific resistance is less accurate than of pressure or temperature coefficient. Two independent comparisons of specific resistance were made. The discrepancies of these two comparisons differed in sign; the average of the two comparisons showed an agreement of specific resistance of 0.06%.

Conclusion.—These measurements establish that any difference between the pressure coefficient of resistance, temperature coefficient and specific resistance is at least many fold less than the difference of the atomic weights. It seems indicated with a high degree of probability that the same conclusion will be found also to apply to the compressibility and thermal expansion. The results fortify the point of view embodied in recent theories of electrical resistance that the processes involved in electrical conduction take place in the outer part of the atomic structure.

[1] Richards, T. W., and Wadsworth, C., 3rd, *J. Amer. Chem. Soc., Easton, Pa.*, **38**, 1916, (221–227 and 1658–1660).

[2] Richards, T. W., *Year Book, Carnegie Inst., Washington*, **16**, 1917, (299–300).

[3] Aronberg, L., *Astroph. J., Chicago*, **47**, 1918, (96–101).

[4] Richards, T. W., and Wadsworth, C., 3rd, *J. Amer. Chem. Soc.*, **38**, 1916, (2613–2622).

[5] Bridgman, P. W., *Proc. Amer. Acad., Boston*, **49**, 1914, (627–643).

[6] Bridgman, P. W., *Ibid.*, **52**, 1917, (573–646).

NATIONAL RESEARCH COUNCIL

EXTRACTS FROM MINUTES OF MEETINGS OF THE EXECUTIVE BOARD, JOINT MEETING OF THE EXECUTIVE BOARD OF THE NATIONAL RESEARCH COUNCIL WITH THE COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES

IN THE UNITED STATES NATIONAL MUSEUM

APRIL 30, 1919, AT 4.55 P.M.

Present: Messrs. Bancroft, Clevenger, Cross, Dunn, Hale,* Leuschner, McClung, Manning, Merriam, Millikan, Noyes,* Ransoms,* Stratton, Walcott,* Woodward, Woods.

Mr. Walcott in the chair during the transaction of the business of the Council of the Academy.

Mr. Merriam in the chair during the transaction of the business of the National Research Council.

The minutes of the meetings of the Interim Committee held April 22, and April 28, 1919, are included in this record.

Mr. Cross, Chairman of the Committee on Organization of Administration, presented a report of progress, recommending that there should be adopted a classification of the entire administrative force of the Council, both scientific and clerical, to serve as a basis for determining responsibility, the method of supervision, and the salary scale, and asked for authorization in behalf of the Committee to take the necessary steps for the establishment of an equitable bonus system. The proposed classification was approved and it was

Moved: That the Interim Committee approve the general plan of a standard salary scale for non-scientific employees of the Research Council with bonuses to meet the increased cost of living and authorize the Committee on Organization of Administration to work out an equitable basis for such bonuses. (*Adopted.*)

At his own request, Mr. Cross was relieved of the chairmanship of the Committee on Organization of Administration, and Mr. Leuschner, Acting Secretary of the Council, was appointed to succeed him as chairman of the Committee.

On recommendation of Mr. Hale, Chairman of the Division of Foreign Relations, the following tentative organization of the Executive Committee of the Division was authorized: Foreign Secretary of the National Academy of Sciences, Chairman; Chairman of National Research Council, Chairman of the Research Information Service, Dr. H. A. Bumstead.

Mr. Washburn, Acting Chairman of the Division of Chemistry and Chemical Technology, requested information regarding the plans of the Government

* Members of the Council of the National Academy of Sciences.

with reference to the publication of results of scientific investigations bearing on the war and regarding the Research Council's connection with any plans the Government might have in this respect.

Moved: That the Research Information Service secure information on the plans of the Government for the publication of results of scientific investigations bearing on the war. (*Adopted.*)

Mr. Clevenger, Acting Chairman of the Division of Engineering, reported the following organization of the committee authorized April 8, to study the relation of Neumann bands in iron and steel to the rate of rupture caused by explosions or other stresses: Professor Charles E. Munroe, Chairman; Mr. S. B. Howell, Mr. F. B. Foley, Professor Albert Sauveur, Professor William D. Campbell, Lieut.-Colonel C. G. Storm, Lieut.-Commander O. M. Hustevedt.

(*Approved.*)

On behalf of the Division of Chemistry and Chemical Technology, Mr. Washburn, Acting Chairman, presented a report on the Publication of Compendia of Chemical Literature, etc. This report was originally prepared by a Committee of the American Chemical Society and later considered and concurred in by the Division.

Moved: That copies of the Report on Publication of Compendia of Chemical Literature, etc., be sent to the members of the Executive Board prior to the next meeting, and that a committee consisting of two members of the Division of Chemistry and Chemical Technology, two members of the Division of Physical Sciences, one member from the Bureau of Standards, and one member from the Smithsonian Institution, be appointed to report on the proposed project at the next meeting of the Executive Board. (*Adopted.*)

The Committee was constituted as follows: Representing the Division of Chemistry and Chemical Technology, Messrs. W. D. Bancroft and E. W. Washburn; representing the Division of Physical Sciences, Messrs. H. A. Bumstead and R. A. Millikan; representing the Bureau of Standards, Mr. S. W. Stratton; representing the Smithsonian Institution, Mr. F. E. Fowle.

Mr. Merriam presented for later consideration the following recommendation of the Committee on Psychology of the Council:

It is recommended by the Committee on Psychology of the National Research Council that the Division of Anthropology and Psychology be constituted of equal numbers of psychologists and anthropologists. It is further recommended that the number for each science be nine. Of the nine members representing psychology the American Psychological Association would nominate six (two each succeeding year), and the National Research Council the remainder (one each year).

Mr. Clevenger, Acting Chairman of the Division of Engineering, reported the election by the Executive Committee of Mr. C. F. Rand as Chairman of the Finance Committee of the Division, vice William R. Walker who is unable to serve.

Mr. Clevenger brought up the question of furnishing the New York Office of the Division of Engineering. After discussion

Moved: That the Division of Engineering be authorized to purchase furnishings for its New York office in the United Engineering Building at 29 West 39th Street, and that a sum of not more than $1400, or as much thereof as may be necessary, be set aside for this purpose from the unappropriated funds at the disposal of the Council. (*Adopted.*)

Mr. Leuschner, Acting Secretary of the National Research Council, presented a preliminary report on the membership of the Executive Board under the new organization of the National Research Council, and indicated that the new Board could not be completely organized at the present meeting.

Mr. Hale, for the committee appointed April 15, to nominate a Chairman and Vice Chairman and not more than ten members at large of the Executive Board, reported that the committee was not prepared to nominate a Chairman at this time, and presented the following names for election as members at large of the Executive Board: Messrs. Dunn, Millikan, Noyes, and Welch.

Moved: That the Acting Secretary of the Council cast the ballot for the election of Messrs. Dunn, Millikan, Noyes, and Welch as members at large of the Executive Board of the National Research Council, and that the President of the National Academy be requested to appoint them members of the National Research Council. (*Adopted.*)

Mr. Leuschner, the Acting Secretary, thereupon reported that he had cast the ballot for the election of Messrs. Dunn, Millikan, Noyes, and Welch as members at large of the Executive Board of the National Research Council, and the Chairman declared these nominees so elected.

In view of the incomplete organization of the new Board it was

Moved: That the former ex-officio members of the Executive Board of the National Research Council continue to serve on the Board until their successors shall have been elected, and that all members at large of the Executive Board continue to serve until the election of members at large shall have been completed and the new members shall have been appointed to the Council. (*Adopted.*)

Mr. Hale, Chairman of the Nominating Committee, stated that two members were leaving Washington and

Moved: That the present Nominating Committee be discharged and the Acting Chairman be requested to appoint a new Committee on Nominations. (*Adopted.*)

At the suggestion of the Acting Chairman, Mr. Merriam it was

Moved: That the Acting Chairman of the National Research Council be authorized to appoint a committee of three to serve on the part of the National Research Council on a joint committee with representatives of the Chemical Foundation, to study and report on the relation of the National Research Council to the Chemical Foundation in regard to the question of chemical research in educational institutions. (*Adopted.*)

The Acting Chairman stated that Mr. A. A. Hammerschlag, director of the Carnegie Institute of Technology, of Pittsburgh, has offered the use of the shops of the institution and the services of its staff to the National Research Council, in connection with research problems which the Council might undertake.

Moved: That a vote of thanks be extended to Dr. A. A. Hammerschlag, director of the Carnegie Institute of Technology, Pittsburgh, by the National Research Council, for courtesies extended in the shops of the Institution to the National Research Council in connection with the work on war problems, and for the offer of further assistance. (*Adopted.*)

Mr. Merriam, in behalf of the Section on Relations with Educational Institutions and State Scientific Committees, under the old organization, recommended that the appointment of chairmen for the Divisions of Educational Relations and of States Relations be deferred, that for the present a Secretary for transacting the business of both be appointed, and that Dr. Albert Barrows, of the University of California, be appointed to this position.

On motion, these recommendations were unanimously approved.

On nomination of the Section on Relations with Educational Institutions and State Scientific Committees it was

Moved: That the President of the National Academy of Sciences be requested to appoint Messrs. S. P. Capen, A. Flexner, H. E. Gregory, A. O. Leuschner, J. C. Merriam, H. S. Pritchett and R. M. Yerkes members of the National Research Council on the Division of Educational Relations. (*Adopted.*)

Moved: That the Division of State Relations include one representative from six organizations concerned particularly with research problems of the state, as follows: Association of American State Geologists, five others to be named. (*Adopted.*)

Mr. Cross, Treasurer of the Council, gave notice at the meeting of the Interim Committee of April 22, 1919, that he had tendered his resignation as Treasurer of the National Academy of Sciences to take effect May 1, 1919.

Mr. Hale presented the following resolutions adopted by the National Academy of Sciences:

That the organization of the National Research Council as presented from the Council of the National Academy of Sciences be adopted as a whole, and that power of amendment be given to the Council of the National Academy of Sciences.

That the Council of the National Academy of Sciences be authorized to represent the Academy in all dealings with the National Research Council.

That the Council of the National Academy of Sciences be authorized (1) to secure funds to meet the needs of the Academy and of the National Research Council (2) to prepare a budget apportioning such funds (3) to select and purchase a site for a building, using any available Academy funds in case a grant for the selection of a suitable building can be secured.

That Section 2 of Article 4 of the Organization of the National Research Council be amended to read:

"Section 2. The affairs of the National Research Council shall be administered by an Executive Board, of which the officers of the Council, the President and Home Secretary of the National Academy of Sciences, the President of the American Association for the

Advancement of Science, the Chairmen and Vice-Chairmen of the Divisions of Science and Technology, and the Chairmen of the Divisions of General Relations shall be ex officio members. The Council of the National Academy of Sciences and the Executive Board of the National Research Council, meeting in joint session, may nominate additional members, not to exceed twelve in number, who, if not already members of the National Research Council, shall be appointed thereto, in accordance with Article V, section 4."

That the Council of the National Academy of Sciences be authorized to proceed with arrangements for the publication of a popular science journal, in co-operation with the American Association for the Advancement of Science, provided arrangements can be made for properly financing the journal and for safeguarding the scientific quality of its contents.

That the following new rules of the National Academy of Sciences be approved:

The Treasurer is authorized to act ex officio as Treasurer of the National Research Council.

It is the opinion of the Council of the National Academy of Sciences that the provision in the Organization of the National Research Council making the Treasurer of the National Academy of Sciences ex officio the Treasurer of the National Research Council should go into effect May 1, 1919, or as soon thereafter as practicable.

This opinion shall be transmitted to the Executive Board of the National Research Council with the suggestion that it should approve the action specified.

On such approval the Chairman of the National Research Council should request the President of the Carnegie Institution of Washington to take such steps as may be necessary to place the account of the National Research Council at the Riggs National Bank in the custody of the Treasurer of the National Academy of Sciences, and to cause further payments from the Carnegie Corporation of New York in support of the National Research Council to be paid directly to the Academy.

Moved: That the Executive Board of the National Research Council approve the action of the National Academy of Sciences suggesting that the provision in the Organization of the National Research Council, in making the Treasurer of the National Academy of Sciences ex officio Treasurer of the National Research Council, should go into effect May 1, 1919, or as soon thereafter as practicable, and that the Chairman of the National Research Council is directed to request the President of the Carnegie Institution of Washington to take such steps as may be necessary to place the account of the National Research Council at the Riggs National Bank in the custody of the Treasurer of the National Academy of Sciences and to cause further payments from the Treasurer of the Carnegie Corporation of New York in support of the National Research Council to be paid directly to the National Academy of Sciences. (*Adopted.*)

That the Treasurer shall have assistance of a salaried and bonded officer, the bursar, who shall be chosen by the Finance Committee and be directly responsible to the Treasurer.

That a Budget Committee on the expenses of the National Academy of Sciences and the National Research Council, to consist of the President of the Academy, the Chairman of the National Research Council, and the Treasurer of the Academy and the Research Council, be appointed, the President of the Academy to act as Chairman.

Concerning notification of present members of the National Research Council that their term of service terminated with the new organization.

Moved: That in ordinary course the Secretary be authorized in his discretion to communicate with the members of the National Research Council under the old organization, stating that the new organization has taken effect and thanking them for their services, which were so patriotically given during the war period. (*Adopted.*)

Mr. Hale stated that it was expected that the National Research Council might change its quarters and that in the new quarters there would be room for exhibits, which are desirable in connection with the work of the National Research Council, and he

Moved: That an exhibit by the Western Electric Company in this connection be authorized. (*Adopted.*)

Mr. Noyes submitted the following draft of recommendations of the Division of Chemistry and Chemical Technology with respect to the formation of an International Chemical Council:

RECOMMENDATIONS OF THE DIVISION OF CHEMISTRY AND CHEMICAL TECHNOLOGY WITH RESPECT TO THE FORMATION OF AN INTERNATIONAL CHEMICAL COUNCIL*

1. That an International Chemical Council be constituted; and that, if possible, arrangements be made for transferring the funds originally given to the International Association of Chemical Societies to this International Chemical Council.

2. That the object of the International Chemical Council be to initiate and promote international coöperation in chemistry; for example, by arranging:

(a) For international coöperation in the preparation and publication of chemical literature.

(b) For the appointment of international commissions to deal with special chemical questions of standardization (such as atomic weights, nomenclature, etc.)

(c) For international coöperation in the prosecution of special research projects.

(d) For the calling of international chemical conferences for various purposes; and also for the organization of an International Chemical Congress with meetings at stated intervals, and including all of the scientific and technological branches of chemistry.

3. That the International Chemical Council be constituted of delegates representing the leading chemical societies and other chemical research organizations of the several allied and neutral countries, these delegates to be selected as described in Paragraph 5.

4. That the International Chemical Council be affiliated with the International Research Council; and that the National Research Council of each country, or its National Academy when no Research Council has been created, act as the intermediary in communications between the International Chemical Council and the chemical organizations of that country, and arrange for the proper representation of those organizations in accordance with Paragraph 5.

5. That the delegates from each country shall in general be chosen by the major chemical societies in that country, but that the number and distribution of such delegates and their voting strength within the delegation be determined initially by the National Research Council of that country, with the understanding that in countries where a National Research Council shall not have been organized the National Academy itself shall fulfill this function until the National Research Council is organized.

6. That upon all questions voted upon by the International Chemical Council the number of votes cast by the various countries shall be determined by their population as follows:

Countries of less than 5 million inhabitants have 1 vote.
Countries between 5 and 10 million inhabitants have 2 votes.
Countries between 10 and 15 million inhabitants have 3 votes.
Countries between 15 and 20 million inhabitants have 4 votes.
Countries over 20 million Inhabitants have 5 votes.

The inhabitants of colonies and possessions are included in the population of the country to which they belong, according to the indications of its Government. Each self-governing Dominion has the same number of votes as an independent country according to the above scale.

7. That the International Chemical Council, as soon as it shall be organized, shall elect an Executive Committee of seven members, which shall exercise such functions as may be assigned to it by the Council. The Executive Committee shall appoint an Executive Secretary, who shall have charge of correspondence and of the central office of the Council.

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*The designation "Council" will probably be changed to "Union" to correspond to similar international organizations in astronomy, geophysics, etc.

8. That until the International Chemical Council shall be organized and its Executive Committee appointed, the Committee on International Coöperation in Chemistry appointed by the Paris Conference shall act as a provisional Executive Committee for purposes of organization. Its membership shall, however, be increased by the addition of four members representing industrial chemistry, to be appointed respectively by the Royal Society of London, the Academie des Sciences de France, the Academia dei Lincei, and the National Research Council of the United States. This Committee shall elect a chairman and a secretary; but the latter need not be a member of the Committee.

SPECIAL MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING

MAY 8, 1919, AT 9.00 A.M.

Present: Messrs. Bancroft, Clevenger, Cross, Leuschner, Manning, Merriam, Ransome, Stratton, Walcott, Washburn, and Yerkes.

Mr. Merriam, Chairman of the Council in the Chair.

The question of moving the National Research Council to more suitable quarters was discussed.

Moved: That a Committee of three in addition to the Acting Chairman of the Council be appointed, with power to act in the carrying out of plans and making arrangements to move the offices of the National Research Council to more suitable quarters. (*Adopted.*)

Appointed: Mr. Walcott, Chairman, Messrs. Cross, Dunn, Merriam.

In accordance with a request received from the American Council on Education, the Acting Chairman, Mr. Merriam, recommended that the representation of the National Research Council on the American Council on Education be increased from one to three members.

Moved: That Messrs. A. O. Leuschner and R. M. Yerkes be added to the representation of the National Research Council on the American Council on Education. (*Adopted.*)

The Chairman presented a communication from Mr. Wm. M. Davis, Chairman of a Committee of the National Academy of Sciences on Pacific Exploration, recommending that a general committee on Pacific Exploration be organized by the National Research Council. In this connection Mr. Mathews, Acting Chairman of the Division of Geology and Geography, reported that the subject of Pacific Exploration had been fully discussed in the Division of Geology and Geography, and submitted a recommendation for the appointment of an appropriate divisional committee.

Moved: That the appointment of a sub-committee on the Exploration of the Pacific by the Division of Geology and Geography be approved; that each of the other Divisions of the Council interested be requested to appoint similar sub-committees; that the chairmen of these sub-committees be members of a general Committee on the Exploration of the Pacific to be appointed by the Acting Chairman; and that Mr. Davis be informed of this action.

(*Adopted.*)

On the recommendation of Mr. Yerkes, Acting Chairman of the Committee of Psychology, it was

Moved: That the Board authorize the expenditure of not to exceed $50.00 for the preparation of a record of war service of American psychologists. (*Adopted.*)

On further recommendation of Mr. Yerkes, presented in the absence of the Acting Chairman of the Division of Medicine, it was

Moved: That the expenditure of a sum not to exceed $300 to further a special study of the intelligence ratings of medical officers in relation to education and professional success, be authorized, it being understood that the sum of $300 is additional to the sum of $800 already available for this purpose. (*Adopted.*)

Mr. Washburn, Acting Chairman of the Division of Chemistry and Chemical Technology reported on the desirability of continuing the Committee on Explosives Investigations.

Moved: That the Committee on Explosives Investigations be continued, and that a conference of representatives of the Division of Chemistry and Chemical Technology, of the Army, of the Navy, and of the Bureau of Mines be held for the purpose of arranging for an annual contribution of $2000 each from the Army, the Navy, and the Bureau of Mines for the support of the work of the Committee on Explosives Investigations. (*Adopted.*)

The Chairman stated that this special meeting of the Executive Board was called for the purpose of electing a Chairman for the National Research Council for the ensuing year which action had not been possible at the meeting held on April 30. In the absence of Mr. Hale, Chairman of the former Nominating Committee, the Chairman presented the name of Mr. James R. Angell, of the University of Chicago, as the unanimous choice of the Nominating Committee for Chairman. Mr. Walcott

Moved: That the report of the Nominating Committee be approved and that the Acting Secretary cast the ballot for Mr. James R. Angell, of the University of Chicago, as Chairman of the National Research Council for the year beginning July 1, 1919.

(*Adopted.*)

The Secretary cast the ballot for Mr. James R. Angell as Chairman of the National Research Council for the year beginning July 1, 1919, and the Chairman announced that the election of Dr. Angell was unanimous.

Mr. Cross reported that his resignation as Treasurer of the National Academy of Sciences and ex-officio Treasurer of the National Research Council had been accepted at the Annual Meeting of the National Academy held April 30, 1919, and that he had turned over all accounts and the books of his office to his successor, Mr. F. L. Ransome. Mr. Cross requested to have his accounts as Treasurer of the National Research Council, including the funds appropriated by the Carnegie Corporation and the Rockefeller Foundation, audited by expert accountants.

Moved: That the report of the retiring treasurer be received and approved, that with the system of auditing of the accounts now in effect it would not be necessary to have the accounts audited at this time on the transfer of the funds, and that a committee of three be appointed to express in a suitable way the appreciation of the National Research Council of the work which Mr. Whitman Cross has so patriotically given to the National Research Council during the period of the war. (*Adopted.*)

Appointed: Mr. Woodward, Chairman, Messrs. Leuschner, Washburn.

The Secretary presented a communication from Mr. Clevenger, Acting Chairman of the Division of Engineering, in regard to the desirability of completing certain war work for the United States Bureau of Mines, and securing financial support and coöperation for the Pulverizing Committee of the Division of Engineering.

Moved: That the Acting Chairman of the Division of Engineering, Mr. Clevenger, be authorized to proceed to Colorado for the purpose of giving personal attention to matters growing out of certain war work for the Bureau of Mines, and for the purpose of securing the financial support and coöperation for the Pulverizing Committee of the Division of Engineering. (*Adopted.*)

Mr. Leuschner, Acting Chairman of the Division of Physical Sciences, reported the election of Mr. C. E. Mendenhall as Chairman of the Division, of Mr. A. O. Leuschner as Acting Chairman of the Division during Mr. Mendenhall's absence in London as Scientific Attaché, and of the following as members of the Executive Committee: William Bowie, R. A. Millikan, H. N. Russell, E. B. Wilson, the Chairman, ex officio, the Vice-Chairman, ex officio.

(*Approved.*)

The Acting Chairman of the Division of Geology and Geography, Mr. E. B. Mathews, presented a report of the meeting of the Division held on May 1 and 2, and announced the following elections:

Vice-Chairman and Acting Chairman, E. B. Mathews; Executive Committee, Isaiah Bowman, Alfred H. Brooks, John M. Clarke, N. M. Fenneman, David White.

Moved: That the appointments be confirmed and that the report be approved. (*Adopted.*)

The Acting Chairman of the Division of Geology and Geography presented a tentative draft of a resolution for submission to the Secretary of War, the Chief of Staff, and the Military Committees of Congress, providing that in the reorganization of the army provision should be made for a number of reserve officers who are primarily scientific experts in physics, chemistry, geography, biology, geology, psychology, mathematics, engineering, medicine, and such other sciences as may be appropriate, and that they be relieved from certain training in order to devote their entire time to research work.

Moved: That the matter contained in the report be referred to a committee to be appointed by the Acting Chairman of the Council in accordance with a previous resolution of the Interim Committee. (*Adopted.*)

Appointed: Mr. Walcott, Chairman, Messrs. Mathews, Leuschner.

The Division of Geology and Geography suggested a survey of (a) the financial resources available for research in existing museums, universities, and allied institutions; (b) the boards or persons controlling the disposal of funds; (c) the discovery of private sources of support, together with best lines of approach.

Moved: That a survey of the kind be approved and referred to the Research Information Service. (*Adopted.*)

Mr. Washburn, Acting Chairman of the Division of Chemistry,

Moved: That a special committee on the Chemistry of Colloids be appointed to undertake the following specific projects:

(1) To arrange a series of lectures on different aspects of colloid chemistry by competent specialists and to make public the fact that such lectures have been arranged for and can be given at any institution or before a meeting of any interested body which will make the necessary financial arrangements with the committee.

(2) To secure the preparation and publication of a text book and laboratory manual on colloid chemistry suitable for use in University courses in this field, bothb ooks to be prepared under the auspices of the Committee and subject to the criticism of its full membership and any other experts which the Committee may desire to consult.

(3) To make a research census of investigations and investigators in the field of colloid chemistry. (*Adopted.*)

Moved: That the Committee on Colloid Chemistry be constituted with the following personnel:

Mr. H. N. Holmes, Oberlin College, Oberlin, Ohio, Chairman.
Mr. Jerome Alexander, 59th Street and 11th Avenue, New York, N. Y.
Mr. W. D. Bancroft, National Research Council, Washington, D. C.
Mr. G. H. A. Clowes, Eli Lilly Company, Indianapolis, Ind.
Mr. W. A. Patrick, Johns Hopkins University, Baltimore, Md.
Mr. J. A. Wilson, 203 Juneau Avenue, Milwaukee, Wis.

(*Adopted.*)

A letter was presented from Dr. Charles E. Munroe, Chairman of the Committee on Explosives Investigations, relating to the appointment of a committee to arrange for a series of coöperative investigations dealing with the specific heats of explosive materials and recommending that a committee of three members, to consist of the Chairman of the Division, the Chairman of the Explosives Investigations Committee, and one additional member (to be selected by them) of recognized standing as an expert in calorimetry, be appointed.

Appointed as third member: Dr. W. P. W. White.

(*Approved.*)

Moved: That the sum of $500 be allotted from unappropriated funds for the use of the Division of Biology and Agriculture. (*Adopted.*)

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING

MAY 13, 1919, AT 9.30 A.M.

Present: Messrs. Bancroft, Dunn, Flinn, Hussey, Leuschner, Mathews, Merriam, Ransome, Washburn, Woods, Woodward, and Yerkes.

Mr. Merriam, Chairman of the Council, in the Chair.

The Chairman announced that President Walcott of the National Academy of Sciences had appointed the following Committee on Nominations of Members at Large of the Executive Board: Messrs. Dunn (Chairman), Merriam and Yerkes. This is a joint committee of the Council of the Academy and of the Executive Board of the National Research Council, appointment of which was provided for at the joint meeting of these bodies held April 30. This Committee will report to a joint meeting of the Council of the National Academy and of the Executive Board of the National Research Council.

The Chairman asked consideration of the number of Vice Chairmen to be elected under the new organization of the National Research Council, the number of Vice Chairmen under the old organization being three.

Moved: That there be three Vice Chairmen in the new organization of the National Research Council. (*Adopted.*)

Mr. Washburn, Acting Chairman of the Division of Chemistry and Chemical Technology, presented an amended report on the organization of the proposed International Chemical Union. The original report was presented at the meeting of the Executive Board on April 15 and was referred to the Division on International Relations. The amended report presented by Mr. Washburn, has been printed with the minutes of April 30.

Moved: That the plan of organization of the proposed International Chemical Union, as circulated with the minutes of April 30, be approved. (*Adopted.*)

Moved: That the whole question of delegates to international conferences to be held during the coming summer, be left to the Interim Committee with power and that the principle be adopted that in naming delegates alternates be named at the same time. (*Adopted.*)

Consideration of this report brought up the question of delegates to the various international conferences to be held in Europe during the coming summer.

Moved: That the question of delegates for the coming meeting of the International Chemical Union be referred to the Division of Chemistry for nominations and that the Division report to the Interim Committee. (*Adopted.*)

The Chairman submitted for consideration the question of the future of the Foreign Research Information Service. Mr. Yerkes, Chairman of the Research Information Service outlined the history of the Service during the war

and presented arguments in favor of its continuation. After thorough discussion in which Messrs. Dunn, Flinn, Leuschner, Merriam, Woods, Woodward, and Yerkes participated, the following motion was made.

Moved: That the Chairman of the Council and the Chairman of the Research Information Service present to the State Department a request that the Foreign Research Information Service be maintained, that the Scientific Attachés be continued at their present posts, that a committee be appointed with power to prepare and present suitable resolutions to the proper authorities in regard to the continuation of the Service, and that authority to present matters concerning international relations in regard to scientific research to the League of Nations at its meeting in Washington be left to the Committee with power.

(*Adopted.*)

Appointed: Messrs. Bancroft, Dunn, Merriam, Mathews, Yerkes (Chairman).

The Chairman submitted for consideration the question of the organization of the Government Division. After a general discussion of the subject in which practically all of the members of the Board participated, it was referred back to the Committee on Organization of the Government Division for future consideration.

The Chairman presented a communication from Mr. Johnston, Chairman of the Section on Industrial Research under the old organization of the Council, proposing that in accordance with action taken on April 8, regarding the organization of the Division of Industrial Relations under the new organization, the membership of the Division be constituted as follows:

The Chairman, Division of Physical Sciences, Charles E. Mendenhall (A. O. Leuschner, Acting Chairman).

The Chairman, Division of Engineering, Henry M. Howe (G. H. Clevenger, Acting Chairman).

The Chairman, Division of Chemistry and Chemical Technology, W. D. Bancroft (E. W. Washburn, Acting Chairman).

One representative of the Bureau of Chemistry, H. D. Gibbs.

One representative of the Bureau of Mines, F. G. Cottrell, (A. E. Wells, Acting).

One representative of the Bureau of Standards, G. K. Burgess.

Members at large of whom one-third shall serve for one year, one-third for two years, one-third for three years, the terms to be determined by lot: Leo H. Baekeland, John J. Carty, Gano Dunn, Alfred D. Flinn, Harrison E. Howe, John Johnston, C. E. K. Mees, Walter Rautenstrauch, C. P. Townsend, E. W. Washburn, and W. R. Whitney. Nomination of the twelfth member at large to be deferred.

Moved: That the foregoing nominations be approved with the recommendation to the President of the National Academy of Sciences that the nominees be appointed members of the National Research Council and assigned to the Division of Industrial Relations.

(*Adopted.*)

The Chairman stated that there was some question as to whether the Research Council should consider the salaries of Government employees having to do with research, in connection with the present movement of reclassification. It was the sense of the Executive Board that no action be taken.

Mr. Yerkes, Chairman of the Research Information Service, presented the following report:

In accordance with the action taken by the Interim Committee April 8, 1919 to the effect "that the Research Information Service secure information on the plans of the Government for the publication of results of scientific investigations bearing on the war," the Chairman of the Division of Research Information has made inquiries in the office of the Secretary of War and of the War Plans Division of the General Staff.

It appears that no general plan for the publication of scientific materials relating to military problems has been formulated. The several military departments or bureaus are proceeding with arrangements for the assembling and publication of their respective materials. It is desired by the Chief of the War Plans Division of the General Staff that plans for the preparation and publication of materials, as well as completed manuscripts, be submitted to him for consideration and approval before further action is taken.

Moved: That the report of Mr. Yerkes with reference to the plans of the Government for the publication of results of scientific investigations bearing on the war be approved and spread on the minutes. (*Adopted.*)

Mr. Dunn asked whether action was being taken in regard to retaining possession of the government furniture now in use by the Council. The Chairman stated that the matter was under consideration and that a report in regard to the same was expected in a short time.

The Secretary presented the report of the Treasurer, which was approved.

PAUL BROCKETT, *Assistant Secretary.*